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A CASE OF PEELING

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Abstract
Peeling of paint and plaster from building facades is a well-known phenomenon. This contribution analyses a case of peeling on a villa and its gardens walls, Figure 1. The walls were levelled with cement plaster, before painted with a formally very dense acrylic paint. - The analysis shows that the present layer of acryl paint is not very dense because it is applied on a rough plaster surface. - However, the main reason of the peeling seems to be the difference in thermal expansion between the masonry and the cement plaster. It is shown that the peeling takes place both winter and summer.

Figure 1. Part of the southern wall of the examined house and its gardens walls.
May 27, 2015, 18.28 o'clock.

1. Introduction

Peeling on painted surfaces of brick masonry, unfortunately, is a rather common phenomenon. In 2015 I had the opportunity to examine a case of such peeling. The work gave some conclusions around the materials and the methods used, conclusions, which I will bring further in the present paper.

The peeling occurs on a villa situated in Nordsjælland north of Copenhagen. It was build in 1960's with facades and garden masonry walls of red tile. Around 1995 the walls were painted with polymer paint. Before the painting the walls were smoothened with cement plaster with thicknesses up to 4 mm. The plaster consists of fine sand and cement as binder. In 2011, before a sale of the villa, the walls were painted again. At that occasion the gardens walls got another layer of plaster, before the painting. In the winter 2011- 2012 the peeling began and is still going on. I had the opportunity to examine the walls in 2015 in connection with a trial about payment of the repair.

2. Theory

If a surface layer of some kind shall fasten on a base of a siliceous material, such as tile or cement plaster, some conditions must be fulfilled.

- Cleaning. The molecules of the surface layer must be in contact with the crystals of the surface, i.e. the surface must be thoroughly cleaned.
- Water diffusivity. The surface layer should be open for water diffusion. Or else there is a risk that in hot weather high stream pressures may occur under the layer, and in cold weather ice lenses may be created.
- Thermal expansion. The surface layer should be so thin that the differences in the thermal expansion properties between the surface material and the base material would not cause mechanical stresses exciding the adhesion between the layers.

In the present case there are two surface layers, the plaster and the paint. The plaster shall fasten to the tile, and the paint shall fasten to the cement plaster.

3. The paint

In trials where painting is involved it seems natural as the first point to examine the paint. So also here. At two different occasions small specimens of the paint and the plaster were analysed at The Danish Technological Institute (DTI). In both cases the outermost paint layer was examined with FTIR (Fourier Transformations Infra Red) analysis, which showed that the binder in the paint was an acryl-styrene copolymer, which seems to be identical to the binder in a paint named Sigmacryl 6.

The specimens were examined on polished sections, Figure 2. The thickness of the inner layer were measured to 0,185 - 0,359 mm, and of the outer layer to 0,066 - 0,350 mm. Further it was observed that the paint contained inorganic material, probably kaolin.

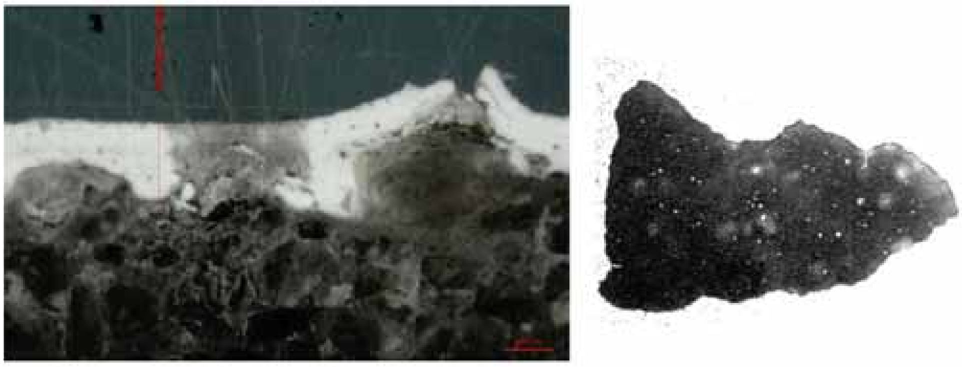

Figure 2, left: Micro photo of cross section of the treatment on the south facade of the house. Lowest the cement plaster (grey and black), above the two white paint layers. The paint layer is broken over a protruding stone. The breath of the picture is equal to 2,5 mm. Photo DTI.
Figure 2, right: A piece of the paint layer in transmitted light. A lot of pinholes are seen. The breath of the picture is equal to 11 mm. Photo AN.

From the type of binder and from the thicknesses of the layers DTI concluded that the paint treatment is not open for diffusion. This conclusion may be taken from the common judgement of the properties of acrylic paint in homogeneous layers of the measured thicknesses. The technical information about Sigmacryl 6 gives the following numbers, valid at 23 ^{O}C, 50 % RH.

Binder	100% acrylic
Dry solids	42 volume%
S_dH_2O	0,17 m at 0,138 mm thickness
S_dCO_2	248 m at 0,157 mm thickness

S_d is a measure of diffusion tightness measured with normalised methods. It tells how many meters of atmospheric air correspond to the specified thickness, if water vapour, or carbon dioxide, respectively, diffuses through air. (The S_dCO_2 value of 248 m indicates that this paint is developed to prevent carbon dioxide diffusion into concrete structures.)

The values mentioned are valid at 23 ^{O}C, 50 % RH. If the paint is applied on an outer wall in Denmark, Danish outdoor climate is valid, including driving rain. You can find no information about this situation. In this case some facts indicate that diffusion values in the practical situation are lower than in the laboratory:

Firstly, the application to the rough surface of the cement plaster gives a paint layer, which in no way is "a homogeneous layer". The paint film is punctured over the protruding sand particles from the plaster, because the capillary forces in the fluid paint draw the film away from the top of the particles, cf. Figure 2.

Secondly, 42 volume % of the paint layer is dry solids, which in this case is kaolin. Kaolin is a clay mineral, which is hygroscopic and will suck water when exposed to rain. It may be illustrated from the following measurements.

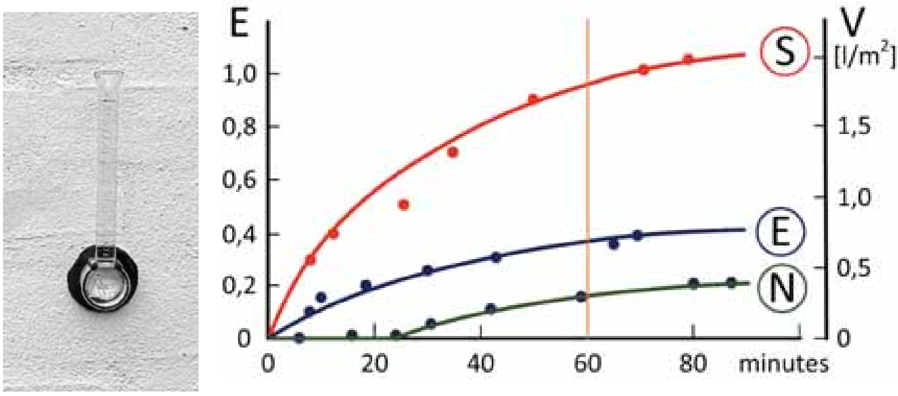

Figure 3. Karsten tube measurements. The glass tube at the device, left, is divided in units, E, which are transformed to suction, V l/m^2. The height of the tube is 15 cm.

The capability of the surface treatment to suck up water was measured on three different walls by means of the so-called Karsten tube, cf. Figure 3. The measurements were taken in May 2015, i.e. four years after the painting. Measurement S was taken at the South faced façade, which is the most exposed. The suction here is around 1,8 l/m^2 after 1 hour. Measurement E is from the East faced façade, which is less exposed. Here the suction is 0,7 l/m^2 after 1 hour. Measurement N was taken on the North faced façade. Here it is seen that nothing happens in the first 24 minutes, hereafter the suction starts. This seems to correspond to the information about the high amount of kaolin in the paint: When the kaolin has expanded due to the water up-take, the paint layer has been opened so much that the water penetration can begin.

However, no facts in the paint analysis give a reasonable explanation to the severe peeling.

4. The cement plaster

The cement plaster used for the smoothening of the masonry is very dense and strong. I have not got any numbers for the properties, but on polished sections it can be seen that the plaster is very dense, cf. Figure 2. The strength is illustrated from the fact that it is not possible to break small pieces with the fingers.

From the literature, e.g. [1], it is known that the thermal expansion of masonry lies in the interval from 5 - 8×10^{-6} $^{o}C^{-1}$ dependent on the type of mortar used. The thermal expansion of cement mortar lies in the interval 8 - 14×10^{-6} $^{o}C^{-1}$, depended on the amount of cement. So, the cement mortar will contract or expand nearly twice as much as the masonry for the same temperature change. Furthermore, at temperature changes the plaster layer is cooled or heated first in relation to the tile. This means that the plaster will try to contract or expand much more than the tile, which again means that contracting or compression forces are created in the plaster. During cooling the contraction may create cracks in the plaster. During heating the compression forces interact around corners and irregularities, giving outward directed

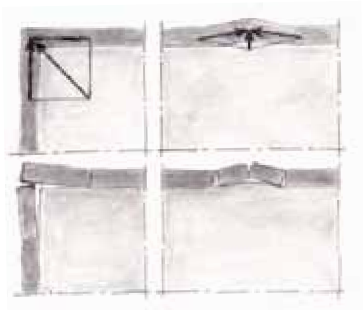

Figure 4. The compression forces in the surface layer cooperate at corners and unevenness's in resultants, which exceed the adhesion, thus causing peeling.

forces exceeding the adhesion; thus the plaster will peel of, cf. Figure 4. For this reason the peeling most often starts at the corners.

The damage does not start at day one. It is necessary with a number of temperature changes where small cracks are developed before the visible peeling starts. But first started, the phenomenon will occur all the year round, because temperature differences occur both summer and winter. This is in opposition to the generally accepted view that the peeling occurs in winter caused by freezing. The pictures on Figure 5 shows that the peeling takes place all the year round. The peeled-of pieces consist of plaster in the whole thickness, leaving the tile exposed.

5. Discussion

In relation to section 2, Theory, the following should be said.

- Cleaning. There is no sign that insufficient cleaning contributes to the damages.
- Water diffusivity. The paint film is medium tight, when tested at standardised conditions at 23 ^{O}C, 50 % RH. It is rather difficult to tell how tight the film will be in outdoor climate and with the many pinholes occurring. - But together with the dense cement plaster the two layers of paint creates a rather dense barrier against water vapour. Meanwhile, the possible damages, which may occur from this reason, have not reached to developed before the damages due to thermal expansion have shown up. - The references [2, 3] deal with wood, where hygroscopic particles in the paint can give problems.
- Thermal expansion. As the peeling occurs all the year round it seems as if the difference in thermal expansion values between the tile and the cement plaster is the main reason of the damages. Frost damages may occur and cooperate with the peeling when cracking first opens the surface. Frost damage on the undamaged parts of the treatment of plaster and paint is unlikely, as water cannot penetrate the combined layer of plaster and paint in a degree, which can create ice-lenses.
- The correct repair in this case will be to remove all plaster and paint, and treat the walls with air lime mortar and lime wash, as should have been done from the beginning.

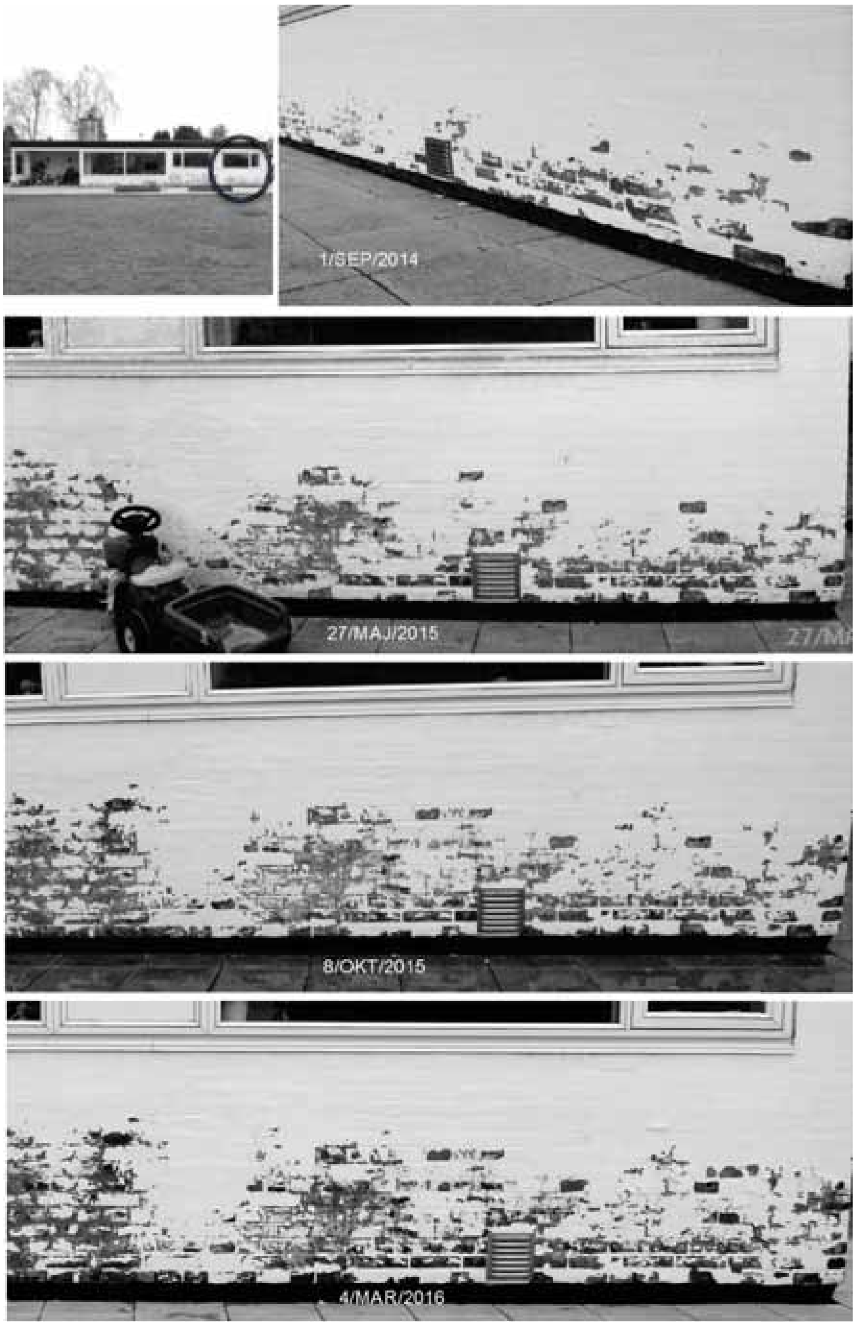

Figure 5. Development of the peeling from September 1, 2014 to March 4, 2016.

6. Conclusions

This examination shows that the paint films on the plastered walls are not tight, as they are perforated with pinholes created above the protruding particles of the plaster. Further it seems as if the hygroscopic filler particles of the paint make the paint film open for capillary suction.

The main cause of the peeling seems to be the difference in thermal expansion between the masonry and the cement plaster. The peeling occurs all the year round.

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